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Experimental Design for Assessment of Electrokinetically Enhanced Delivery of Lactate and Bacteria in 1,2-cis-dichloroethylene-Contaminated Limestone

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Background/Objectives. Leakage of chlorinated solvents into limestone aquifers from contamination in overlying deposits and long-lasting back diffusion from the limestone matrix pose an increasing threat to drinking water supplies, e.g., in Denmark. Often dechlorination of PCE and TCE contamination in limestone accumulates cis-DCE due to inadequacy of advection-based remediation technologies to deliver bioremediation additives. Therefore, there is a need for a remediation scheme capable of establishing contact between the contaminant, bacteria capable of degrading cis-DCE, and donor within the low permeable limestone matrix. EK offers some unique transport processes, which potentially overcome the diffusion limitations of ERD. A novel technology combines ERD and EK for enhanced delivery. The combined technology (EK-BIO) has shown promising results in the low-permeable media clay. However, until now no studies have been performed with limestone.

Approach/Activities. A bench-scale study of transport during EK-BIO in limestone was performed. Focus was on the transport abilities of EK for enhanced delivery of the donor lactate and a bacteria culture containing the dehalorespiring bacteria *Dehalococcoides (Dhc)* in limestone cores contaminated with cis-DCE. For the experiment, methods were developed for sampling of intact bryozoan limestone cores, saturation and contamination of the limestone cores using vacuum properties, and for monitoring throughout the limestone cores. In addition, an experimental set-up was designed to comply with the challenges of EK-BIO in limestone, e.g., the strict anaerobic bacteria, volatile contaminants and extreme pH developments prompted by electrode processes. The latter can be severe for the degrading bacteria if not managed.

Results/Lessons Learned. An experimental setup was successfully designed. However, issues with the recirculation pumping for neutralization of pH were experienced. Therefore, suggestions for improvements of the experimental design were made. The performed preliminary test and assessment of EK-BIO in limestone revealed a critical pH development in the electrode compartments. Nevertheless, the buffering capacity of the limestone maintained a pH range within the limestone appropriate for the *Dhc*. Observations on transport processes included faster diffusion in the control reactor without EK, than predicted. However, the delivery of the donor lactate was uneven, whereas migration of bacteria was not observed. For the reactor exposed to EK, lactate was delivered more evenly by electromigration causing an increase in electric conductivity. Furthermore, fermentation of lactate with an increase in pH indicated migration of bacteria by electrophoresis. Whereas, an initial test on EOF in limestone as well as the assessment of EK-BIO indicated that the properties of limestone hindered the establishment of EOF as opposing to clay.

During the experimental work on EK-BIO in limestone, EK was demonstrated to be promising in establishing enhanced contact between the donor lactate, bacteria and the chlorinated compound cis-DCE within the limestone matrix. Therefore, degradation is expected to occur. Thus, back diffusion limitations in the limestone matrix potentially are overcome, which is essential for the overall time perspective of a remediation.